Pilot Demonstrations of Arsenic Removal Technologies - Sandia National Laboratories

The Arsenic Water Technology Partnership (AWTP) program is a multi-year program funded by a congressional appropriation through the Department of Energy to develop and test innovative technologies that have the potential to reduce the costs of arsenic removal from drinking water. The AWTP members include Sandia National Laboratories, the American Water Works Association (Awwa) Research Foundation and WERC (A Consortium for Environmental Education and Technology Development). The program is designed to move technologies from bench-scale tests to field demonstrations. The Awwa Research Foundation is managing bench-scale research programs; Sandia National Laboratories is conducting the pilot demonstration program and WERC will evaluate the economic feasibility of the technologies investigated and conduct technology transfer activities.

The objective of the Sandia Arsenic Treatment Technology Demonstration project (SATTD) is the field demonstration testing of both commercial and innovative technologies. The scope for this work includes:

1. Identification of sites for pilot demonstrations
2. Accelerated identification of candidate technologies through Vendor Forums, proof-of-principle laboratory and local pilot-scale studies, collaboration with the Awwa Research Foundation bench-scale research program and consultation with relevant advisory panels
3. Pilot testing multiple technologies at several sites throughout the country, gathering information on:
   a. Performance, as measured by arsenic removal
   b. Costs, including capital and Operation and and Maintenance (O&M) costs
   c. O&M requirements, including personnel requirements, and level of operator training
   d. Waste residuals generation

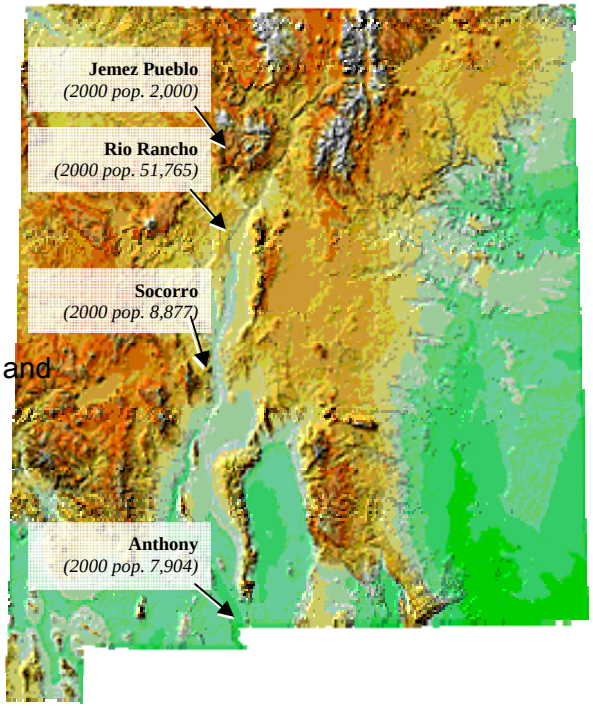

Figure 1. Location of New Mexico Pilots

The New Mexico Environment Department has identified over 90 public water systems that currently exceed the 10 µg/L MCL for arsenic. The Sandia Arsenic Treatment Technology Demonstration project is currently operating pilots at three sites in New Mexico. The cities of Socorro, Anthony, and Rio Rancho vary in population, water chemistry, and source of arsenic. Figure 1 shows the the locations of each city. The following pages summarize the work being performed at each site.

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At each site, the owners (e.g. city utility) provide access to the site, water, electricity, means to discharge treated water, and daily operational checks. Daily checks include filling out a logsheet with information on the flow rates, pressure drops, flow adjustments (when needed), and notification of Sandia personnel if a leak is present.

Sandia owns all equipment and is responsible for the disposal of spent media and other waste streams. Sandia also performs all field tests and collects water samples for laboratory analysis.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Pilot Demonstration Water Chemistry Summary:

Sandia has operated pilots at four locations in New Mexico (Socorro, Anthony, Rio Rancho, Jemez Pueblo) and one in Weatherford, Oklahoma. Each site was chosen in part for its water chemistry. The goal was to get a variety of water types that other utilities could compare with their site. Table 1 below summarizes the salient chemistry points.

Table 1. SNL Arsenic Pilot Water Chemistry Summary

	Socorro	Anthony	Rio Rancho	Jemez Pueblo	Weatherford, OK
Total As (ppb)	42	20	20	20	30-4020-40*
% Arsenite (As(III))	< 5%	9095%	< 5%	95%	70-80%No Data
V (ppb)	11	<5	15.5	<1	2025-3035*
SiO_2 (ppm)	25	37	25	50	24
SO_4 (ppm)	30	180	110105	2425	140
Ca (ppm as $CaCO_3$)	4440	70	5550	155150	200
Fe (ppm)	0.04< 0.1	0.2-0.5	0-0.15	1.20	0.5-1.0
pH	8.0	7.7	7.5	7.5	7
Conductivity (μS/cm)	340350	1300	620600	770880	560
Alkalinity (ppm as $CaCO_3$)	130	180	160	290300	125
TOC (ppm)	0.50	0.8070	0.30	21.5	No Data
NO_3 (ppm as N)	0.40	0ND	2	0ND	No Data
F (ppm)	0.5060	0.50	0.90	1.3	0.40

*Weatherford Arsenic varies as the well is used (i.e. increased pumping yields lower As values)

Pilot Demonstration Site: Socorro, NM

The first pilot demonstration began in the winter of 2004 at Socorro Springs in Socorro, New Mexico. The verification test site (the "Springs Site") is located off Evergreen Road in Socorro, NM. Socorro and Sedillo springs supply continuous water to the Springs Site. These sources are spring boxes located in the foothills west of the City of Socorro, approximately three-quarters of a mile to the southwest at an elevation approximately fifty feet above the Springs Site. Water from both springs is mixed slightly down gradient of the spring boxes, followed by a shut-off valve. Below the shut-off valve, an eight-inch subsurface, carbon steel line delivers via gravity the approximately 540 gpm, 90°F water to the chlorination building where the water is disinfected and oxidized using chlorine gas injection just prior to storage in the Springs Site Storage Tank. Overflow from the Springs Site Storage Tank flows via gravity to a second storage tank located approximately one mile to the east. A summary of the water chemistry and adsorption media tested is shown in Table 2.

Table 2. Adsorption Media Tested at Socorro Springs Pilots (Phases 1 & 2)

PHASE 1	
Media Type	**Vendor/Media**
Iron oxy/hydroxide	Engelhard/ARM 200
Iron-impregnated resin	Purolite/ArsenX^{np}
Titanium Oxide	Hydroglobe/Metsorb
Zirconium Oxide	MEI/Isolux
Iron oxy/hydroxide	AdEdge/E33 (2 min)
Iron oxy/hydroxide	AdEdge/E33 (4 min)
Iron oxy/hydroxide	AdEdge/E33 (5 min)

PHASE 2	
Media Type	**Vendor/Media**
Iron oxy/hydroxide	Kemiron/CFH12
Iron/Copper oxy/hydroxide	Sandia/SANS
Iron-impregnated resin	Purolite/ArsenX^{np}
Titanium Oxide	Hydroglobe/Metsorb
Zirconium Oxide	MEI/Isolux

The pilot test equipment is located in the chlorination building (Figure 2). Phase 1 of this pilot tested five different adsorbent media, including two iron-based sorbents, one zirconium oxide, one titanium oxide, and one resin (Table 2). In addition, a study was performed on the effects of differing empty bed contact times (EBCT) on E33 media. EBCT is a measure of how long the water is in contact with the arsenic removal media. The study was on 2-minute, 4-minute, and 5-minute EBCT. The ambient pH (near pH 8.0) was utilized for this phase.

Figure 2. Socorro Springs Chlorination Building

Phase 2a of this pilot evaluated the additional capacity in several of the Phase 1 media with pH adjustment to 6.8 as well as the effects of flow interruption. This test was performed on E33 (2 and 4 minute EBCT), ARM200, ArsenX^{np}, and Metsorb after the columns had arsenic values above 10 ppb.

Phase 2b is evaluating pH adjustment to 6.8 and new media. The test will test five media in each pH (8.0 and 6.8). In addition, several new media from universities and the AwwaRF program will be tested.

The second pilot demonstration began in the summer of 2005 in Anthony, New Mexico. The verification test site is the Desert Sands Mutual Domestic Water Consumers Association (MDWCA) Well Site #3, or simply the "Desert Sands site", located just off I-10 in Anthony, New Mexico. Desert Sands serves a segment of the Anthony population (approximately 1,820) from two wells in a rural community along the New Mexico-Texas line, north of El Paso. It has a new water treatment plant built by Severn Trent Corp. that uses the iron oxide treatment method. The two wells pump 240-270 gpm directly into the distribution system and from it fill two storage tanks located adjacent to each other. The system is operated by radio telemetry. Typical water production is 2-4 million gallons per month, or 29 million gallons per year.

The EPA conducted a separate full-scale demonstration study at the site using a Granular Ferric Oxide adsorptive media (E33) system from Severn Trent/AdEdge with chlorinated well water. The EPA study provided full scale performance and cost data and was been in progress for two years. The Sandia study will provide estimates of the capacity (bed volumes until breakthrough at 10 ppb As) of other adsorptive media in the same chlorinated water. Table 3 summarizes the adsorption media being tested. Figure 3 shows the pilot equipment skid.

Figure 3. Desert Sands Pilot Equipment

Table 3. Adsorption Media Tested at Desert Sands Pilot

Media Type	Vendor/Media
Zirconium Oxide	MEI/Isolux
Amended Silicate	ADA/Am Si
Iron oxy/hydroxide	Kemiron/CFH12
Iron oxy/hydroxide	AdEdge/E33
Iron oxy/hydroxide	Engelhard/ARM200
Iron/Copper oxy/hydroxide	Sandia/SANS
Iron-impregnated resin	Purolite/ArsenX^{np}
Iron-coated resin	Resin Tech/ASM 10HP
Titanium Oxide	Hydroglobe/Metsorb
Titanium Oxide	Dow/Adsorbsia GTO
La-Coated DE	Eagle Picher/NXT-2
Modified Alumina	Virotec/Bauxsol
Iron-coated Pumice	UTEP/Redisorb
Manganese Dioxide-based *(As, Fe, Mn removal media)*	AdEdge/AD-26

The third pilot project began in the fall of 2005 at Rio Rancho, NM. The verification test site is Well Site #21, or simply the "Rio Rancho site", located just off Loma Colorado Drive near the city's high school in Rio Rancho, New Mexico. The well pump capacity is 2000 gpm; the water is directed into a distribution system nearby. The pilot equipment is housed within a metal storage transportainer. The transportainer, RRNM Well #21 building, power drop and the RRNM sanitary sewer connection are secured within a six foot chain link fence. The transportainer is heated by a small unit heater, and cooling is by a small air conditioner. Temperatures will be between 50-80^{o}F. Chlorinated water is provided to the pilot test equipment at pressures from 70-80 psi.

The city of Rio Rancho operates multiple wells to serve a fast growing population near 62,000. The information from the test will help the city of Rio Rancho determine whether a cost effective adsorption strategy is viable for their water chemistry. They are currently in the design process for arsenic removal systems at each of their affected wells. Table 5 summarizes the adsorptive media and reverse osmosis systems tested at the Rio Rancho Well #21 site. Figure 4 shows the pilot equipment.

Table 4. Adsorption Media Tested at Rio Rancho (Phases 1 and 2)

PHASE 1	
Media Type	**Vendor/Media**
Zirconium Oxide	MEI/Isolux
Iron oxy/hydroxide	Kemiron/CFH12
Iron oxy/hydroxide	AdEdge/E33
Iron-impregnated resin	Purolite/ArsenX^{np}
Iron-coated resin	Resin Tech/ASM 10HP
Titanium Oxide	Dow/Adsorbsia GTO
Reverse Osmosis	Watts Premier/KP4
Reverse Osmosis	Watts Premier/ZRO

PHASE 2	
Media Type	**Vendor/Media**
Zirconium Oxide	MEI/Isolux
Iron oxy/hydroxide	Kemiron/CFH12
Iron oxy/hydroxide	AdEdge/E33
Iron-impregnated resin	Purolite/ArsenX^{np}
Iron-coated resin	Resin Tech/ASM 10HP
Titanium Oxide	Dow/Adsorbsia GTO
Amended Silicate	ADA/Am Si
Iron/Copper oxy/hydroxide	Sandia/SANS
Bone Char	Brimac

Figure 4. Rio Rancho Pilot Equipment

The fourth pilot began in early spring of 2006 at the Jemez Pueblo. The population living at the Pueblo is near 2000. The Pueblo of Jemez is the only remaining village of the Towa-speaking pueblos in NM. Most tribal members reside in the village known as Walatowa (a Towa word meaning "this is THE place". Water and sewer systems are provided by the Pueblo of Jemez Public Works Department.

The verification test site is located in Jemez Pueblo, NM along New Mexico State Road 4 northeast of San Ysidro, NM. The Jemez Pueblo water system has a design capacity of 400 gpm supplying 550 connections for 2000 people. The source of the supply water for Well #2 is a single well approximately one mile west of the treatment facility just west of the Jemez River in the Jemez Valley. The Pueblo also has another well for emergency backup, but its water is not sent to the Jemez iron and manganese removal plant. Existing water treatment consists of the addition of hypochlorite for disinfection and secondarily for the oxidation of iron, arsenic, and manganese in the water prior to filtration. Filtration is by a pressure filter supplied by Filtronics and is specifically designed for arsenic, iron and manganese removal. It is anticipated that the new well will meet community demand by operating for 8 to 12 hours per day; therefore, the water supply for pilot testing will be intermittent daily.

The Sandia Pilot program tested four different vendors' coagulation-assisted filtration (C/F) technologies: Kinetico, Hungerford and Terry, Orca, and Blue Water Treatment. Each utilized different methods and filtration media to accomplish arsenic, iron, and manganese removal. The goals for each pilot were to determine the optimal oxidant and coagulant dosages, as well as to test the operating capabilities of each C/F system. Table 5 summarizes the coagulation-assisted filtration systems. Figure 5 shows each of the pilot units and the Jemez Pueblo site.

Table 5. C/F Technologies Tested at Jemez Pueblo

Item	Kemiron	Hungerford & Terry	Orca	Blue Water Technology
Model	PF100	Greensand Plus Pilot Unit	KemLoop 1000	BWT-BPRO-3
Filter Module Surface Area, ft^2	0.5	0.5	4.9	3
Filter Module Volume, ft^3	1 (per vessel)	1	19.6	70
Media Depth, in	24	36 (18" each of Greensand Plus, Anthracite)	34	60
Number of Filter Modules	2 (only 1 operates at a time)	1	2 (only 1 operates at a time)	1
Filter Pressure Rating, psi	100	100	75 psi	-na-, open top, not a pressure vessel
Filtration Media Description	M2 Macrolite, ceramic	Greensand Plus, Anthracite	2 tanks: • #30 silica sand, coarse and fine garnet, anthracite • Quantum DMI-65, coated silica	Silica Sand, 12-20 mesh, >98% silica
Operational Characteristics	Automated PLC Controlled	Manual	Automated PLC Controlled	Manually operated, Digital Data loggers; Upflow, sand filter
Pre-Treatment Requirements	Oxidant, $FeCl_3$, $KMnO_4$ (Mn removal only)	Oxidant, $FeCl_3$	Oxidant, $FeCl_3$	Oxidant, $FeCl_3$
Dimensions	26" W x 62" L x 68" H	4' W x 4' L x 6' H	8' x 14' open skid	8' x 14' open skid
Location	Indoors	Indoors	Outdoors	Outdoors

Hungerford & Terry

Orca

Blue Water Technologies

Kinetico

Figure 5. Jemez Pueblo Treatment Plant and Pilot Systems Tested

Pilot Demonstration Site: Weatherford, OK

The last pilot is located in Weatherford, OK, which is located 60 miles from Oklahoma City and supplies a population of approximately 10,400. It obtains its raw water from approximately 30 wells. The City supplies water to its customers via two entry points to the distribution system (EPDS). This mode of operation allows blending to occur prior to the EPDS to reduce the contaminant concentrations from individual wells. The estimated arsenic level at the two EPDS ranges from 11 to 29 ppb. The pilot study will be conducted at Well#30 which has an arsenic concentration of around 40 µg/L, of which the majority of arsenic is present as arsenate. This Pilot study will evaluate adsorption (four media) and coagulation/filtration technologies.

The well pump capacity is 30 gpm; the water is directed into a distribution system nearby. The pilot equipment is housed within a metal storage transportainer located outside the fenced well area. Temperatures will be between 50-80^{o}F. Unchlorinated water is provided to the pilot test equipment at pressures from 70-80 psi. Table 6 summarizes the equipment and media tested in this pilot. Figure 6 shows the pilot units.

Table 6. Technologies Tested At Weatherford Pilot

Media Type	Vendor/Media
Iron oxy/hydroxide	Kemiron/CFH12
Iron oxy/hydroxide	AdEdge/E33
Iron-impregnated resin	SolmeteX/ArsenX^{np}
Titanium Oxide	Dow/Adsorbsia GTO
Coagulation-Filtration	TBD

Figure 6. Pilot Equipment at Weatherford Pilot

Pilot Results – As of 7/31/06:

Manufacturer	Media	SS Phase 1	SS Phase 2b (pH 6.8/ pH 8)	RR Phase 1	RR Phase 2	DS (Phase 1/2)
MEI	Isolux	32,000	92,000/28,000	>11,000	20,000	>18,000
Sandia	SANS	N/A	>53,000/31,000	N/A	>40,000	>30,000
Kemiron	CFH10	N/A	28,000 (pH 8)[1]	>22,000	N/A	N/A
Kemiron	CFH12	N/A	>46,000/18,000	N/A	>22,000	>32,000
AdEdge/STS	E33	26,000/44,000/53,000 (2/4/5 min EBCT)	N/A	>25,000	>40,000	>33,000
Engelhard	ARM200	9,000 [2]	N/A	N/A	N/A	18,000 (Ph1)[2]
Dow	Adsorbsia™ GTO™	N/A	N/A	>22,000	>40,000	25,000 [3]
Hydroglobe	Metsorb	13,000 [3]	45,000/22,000	N/A	N/A	28,000 [3]
Purolite	ArsenX^{np}	28,000 [4]	>60,000/37,000	>35,000	36,000	>10,000[4]/>24,000
Resin Tech	ASM-10HP (1st batch)	N/A	N/A	18,000	N/A	8,500
Resin Tech	ASM-10HP (2nd batch)	N/A	N/A	N/A	13,000	N/A
EP Minerals	NXT-2	N/A	N/A	N/A	N/A	2,400 [5]

[1]The Kemiron media installed in Socorro Phase 2b was CFH12, a larger diameter particle, which may not have been conducive to the 3" column size & pilot flow rates. The smaller diameter particle (CFH10) was installed for comparison in the ambient stream only.

[2]The media installed in Socorro Phase 1 from Engelhard was a pre-production media, as stated by the vendor, Engelhard. Newer media is currently being tested at the Desert Sands site.

[3]These media had clogged and flow stopped. Both had reached As>10 ppb for at least one data point.

[4]Purolite indicated a Quality Control problem with the first supplied batch of ArsenX^{np} media. A new batch was installed at Socorro Phase 2, Rio Rancho (both phases), and Desert Sands Phase 2.

[5]This media broke down physically, causing total clogging of the column. The vendor has provided an improved media that is currently being tested at the Desert Sands site.

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